DOES EXTERNAL DISTRACTION AFFECT WORKER PERFORMANCE UNDER TASK LIGHTING AS MUCH AS WITH GENERAL LIGHTING

by

RAIED AL-MISHHEDANI

B.A. (Statistics), College of Economics and Administration, Al-Mustansiriyah University
Baghdad, Iraq, 1976

A MASTER'S THESIS

Submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering
KANSAS STATE UNIVERSITY
Manhattan, Kansas

1984

Approved by:

Major Professor

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENT	iii
LIST OF TABLES	iv
LIST OF FIGURES	vii
INTRODUCTION	1
Task Lighting versus General Lighting	4
Distraction	10
PROBLEM	13
METHOD	14
Subjects	16
Task	25
Experimental Design	27
Subjective Evaluation	30
RESULTS	32
Subject Performance	32
Subject Ratings	35
Number of Look-ups	43
DISCUSSION	50
Subject Performance	50
Subject Ratings	56
Number of Look-ups	60
Implications	66
CONCLUSION	67
REFERENCES	68

ACKNOWLEDGMENT

The author wishes to express his thanks to the students and other people who contributed their time and efforts as subjects in this study.

I am also indebted to Dr. Corwin A. Bennett, a professor with such a kind hearted nature and patience, for his interest, encouragement, and guidance throughout the thesis work.

LIST OF TABLES

		Page
TABLE 1.	Anspil recommendations for Design and Use of Lighting.....	3
TABLE 2.	The contents of the video tapes..	23
TABLE 3.	The order of the tape assigned to the subjects.....	24
TABLE 4.	The order of the task assigned to each subject.....	31
TABLE 5.	Letter crossing task : Errors (no. of mistakes committed).....	33
TABLE 6.	Letter crossing task : Time to perform the task (in minutes)....	34
TABLE 7.	Letter crossing task : Analysis of variance on errors committed..	38
TABLE 8.	Letter crossing task : Duncan's multiple range test for the task means as errors is the criterion	39
TABLE 9.	Letter crossing task : Subject ratings for the difficulty of each task.....	40
TABLE 10.	Letter crossing task : Analysis of variance on subject ratings	41
TABLE 11.	Subject ratings : Duncan's multiple range test for the task means.....	42

TABLE 12. Subject's ratings : Duncan's multiple range test for the interaction between task and distraction means..... 44

TABLE 13. Letter crossing task : The number of look-ups data..... 45

TABLE 14. Letter crossing task : Analysis of variance for the number of look-ups 46

TABLE 15. Number of look-ups : Duncan's multiple range test for the task means..... 48

TABLE 16. Number of look-ups : Duncan's multiple range test for the interaction between task and distraction means..... 49

TABLE 17. Correlation between subject performance and the number of look-ups..... 58

TABLE 18. Correlation between subject rating and the number of look-ups..... 64

LIST OF FIGURES

Page

FIGURE 1. A drawing-board illuminated by a task lighting 8

FIGURE 2. A drawing office illuminated by general lighting..... 9

FIGURE 3. The four experimental conditions 15

FIGURE 4. Task lighting with no distraction 17

FIGURE 5. Task lighting with distraction. 18

FIGURE 6. General lighting with no distraction 19

FIGURE 7. General lighting with distraction 20

FIGURE 8. The arrangement of the furniture 21

FIGURE 9. The arrangement of the television and video recorder..... 22

FIGURE 10. Instructions for the subjects ... 28

FIGURE 11. Informed consent statement form 29

FIGURE 12. The design of the experiment model 36

FIGURE 13. Summary of the analysis of variance table..... 37

FIGURE 14. The mean number of errors committed under the two lighting conditions... 52

FIGURE 15. The mean number of errors committed under the two distraction conditions 55

FIGURE 16. Relation between subject ratings and subject performance..... 59

FIGURE 17. Relation between subject performance

and number of look-ups 63

FIGURE 18. Relation between subject ratings and number of look-ups..... 65

INTRODUCTION

Lighting is an important factor needed to achieve good performance. Light is defined as the aspect of radiant energy of which an observer is aware through the stimulation of the retina of the eye.

The purpose of lighting has been regarded previously to provide sufficient illumination on the work to enable people to perform their tasks. Most efforts regarding the improvement of lighting conditions have been dedicated to this objective.

The purpose of industrial lighting, according to The American National Standard Practice for Industrial Lighting (1979), is to provide energy efficient illumination in quality and quantity sufficient for safety and to enhance visibility and productivity within a pleasant environment.

In designing of industrial lighting systems, much emphasis has always been placed on the supply of sufficient task illumination for safe human performance with a minimum seeing effort. Recent years however, have seen the tendency on the part of designers to use light not only to enhance the safety and productivity but also to create more attractive work places (Misra, 1982).

Weston (1949), found that lighting and the intensity of illumination are related to the productivity of workers.

Lighting today is being evaluated more and more on the basis of a " tool of production ". Better lighting often results in improved production. Boynton and Boss (1971); and Blackwell and Scott (1973), confirmed the theory that, generally, more light means better performance.

Lighting can provide efficient and comfortable seeing as an aid to office operations and to help provide a safe, pleasant, comfortable and satisfactory working environment (American National Standard, 1973).

The design of a lighting scheme depends to a very great extent on the task characteristics, and visual task (Misra, 1982). The American National Standard Practice for Industrial Lighting (1979), gives a list of twelve recommendations that are based on human needs and energy concern, to be included in any industrial lighting design. Furthermore, The American National Standard Practice for Industrial Lighting (1979), has given a classification of visual tasks such as manufacturing, inspection, engraving, and other industrial activities, and the lighting techniques to be used for each specific activity (see Table 1).

Recent studies concerning aesthetic lighting have showed the effect of several major parameters of lighting of subjective impressions. One major parameter is lighting setting

TABLE 1

Anspil*recommendations for Design and Use of Lighting

(Source : ANSI/IES RP-7-1979).

1. Design lighting for expected activity (light for seeing tasks with less light in surrounding non-working areas).
2. Design with more effective luminaires and fenestration.
3. Use efficient light sources (higher lumen per-watt output).
4. Use more efficient luminaires.
5. Use thermal-controlled luminaires.
6. Use lighter finish on ceilings, walls, floors, and furnishings.
7. Use efficient lamps.
8. Turn off lights when not needed.
9. Control window brightness.
10. Utilize daylighting when practicable.
11. Keep lighting equipment clean and in good working condition.
12. Post instructions covering operation and maintainence.

* = American National Standard Practice for Industrial Lighting

which includes lighting distribution (Uniform versus non-uniform) and lighting pattern (overhead versus peripheral). Uniform lighting produces high ratings of visual clarity and non-uniform lighting has high ratings of pleasantness, preference and relaxation (Yuan, 1980).

Task Lighting versus General Lighting

Lion (1964) made a study on the influence of tungsten versus fluorescent systems giving the same level of illumination upon performance of three manipulative and one inspection task. As a result, she found that, the type of lighting did not affect worker performance of the clerical task.

William (1975), suggested for the lighting designer to use more efficient lamps and luminaires and put the correct amount of light where it is needed, in order to eliminate inefficiency and waste in energy use.

Prior to 1973, lighting practice was based on an assumption of plentiful and inexpensive electric energy. Lighting system design was based on a uniform lighting concept[1]. It was found however, the uniform lighting was not always satisfactory (Hopkinson and Longmore, 1959; Taylor, Sucov and Shaffer, 1975; Henderson, McNelis and William, 1975).

Rising energy costs and the energy crisis demanded the lowest possible consumption of electrical power, and triggered several changes in general lighting practices in the United States.

1 This concept implies a uniform quantity of illumination is provided throughout a given area and therefore to the various work stations within a given area.

The two major chages were more extensive use of high intensity discharge lamps and the development of task/ambient lighting system (Yuan, 1980). Dorsey reported in 1978 that the total potential, if the least efficient lighting was converted to the most efficient lighting, would be nearly a forty percent reduction in kilowatt hour consumption.

In studying the problem and the potential solution to the lighting of open office systems, Lemons, Fles, and Cole (1977), suggested that ceiling-mounted illumination systems are appropriate for large areas involving rows of desks because these do not have to be relocated or rewired for a change of office layout. However, the great challenge to the ceiling-mounted system is now presented by the attempts to change from uniform to task/ambient lighting methods to achieve energy saving. It has also been found that office changes take place about every three years which adds to the challenge for a task/ambient lighting system. The use of partitions, overhead storage, files and cabinets rising above working surfaces in open plan offices adds to the problems confronting the lighting designer. Shadows, dark vertical surfaces and dark cavities which resulted around work stations are easily eliminated by installing lights in, under, along and over the stations.

Ambient lighting can be provided from luminaires mounted atop office furniture in the space with no physical attachment to the building structure. This ambient lighting is

usually directed upward in order to bounce light off the ceiling for general illumination. Built-in task lighting is directed from some point above the task. The task lighting fixture may be built on the partitions either over the desk or side table or both. Direct lighting has the advantage of being the most efficient in terms of utilizing luminous flux in a space. However, by directing the light straight down to the work surfaces, the system has the greatest potential for producing direct glare or veiling reflections which cause a loss of visual performance (Yuan, 1980).

Lemons and Cole (1977), using scale models to investigate office system furniture showed indirect lighting systems can eliminate glare and improve task contrast. In addition, indirect light also creates a comfortable and relaxing environment.

The advantages of task lighting over general lighting have been mentioned in a survey of Pros and Cons (1979). One of these advantages is flexibility. The flexibility of a task/ambient system allows the lighting fixtures to move wherever the furniture moves instead of approximating where and what the light will hit with general illumination. Saving energy, and the ability to satisfy the visual needs of all office workers are other advantages of task lighting over general lighting.

Finally, task lighting creates an environment where the user can devote his full concentration/attention on the work he performs. This is because this kind of lighting illuminates a well-defined area or the work station, and the remaining or surrounding area remains darker. Subsequently, no source of noise or other form of distraction can break the user's attention. and thereby his performance.

Hopkinson and Longmore (1959), said : " The attention held by objects which contrast strongly with their environment either by their brightness, color, texture or form. Equally attention can be distracted by a bright or highly colored object close to the object of regard. " They suggested using local lighting (Task lighting) instead of general lighting for work which demanded a high degrees of visual skill and attention. Figures 1 and 2 illustrate the extremes of the two types of lighting. Figure 1 shows a drawing-board illuminated by a task lighting alone. The illumination level was about 100 lumens/sq. ft. on the work, but the surroundings were dark. There is an overwhelming attraction of the eyes by the bright patch, and it is difficult to draw the eyes away from the work. Figure 2, on other hand shows a modern drawing office with general lighting alone. There is rather less light on the work (about 50 lumens/sq. ft.) and the ceiling is much brighter. The ceiling consequently acts as a strong distraction to the eyes to look-up from the work.

Finally, Hopkinson and Longmore (1959), considered that

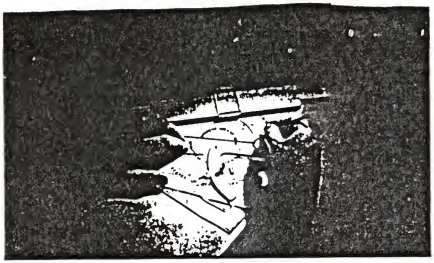


Figure 1. A drawing-board illuminated by a task lighting. (Source: Hopkinson & Longmore, 1959)

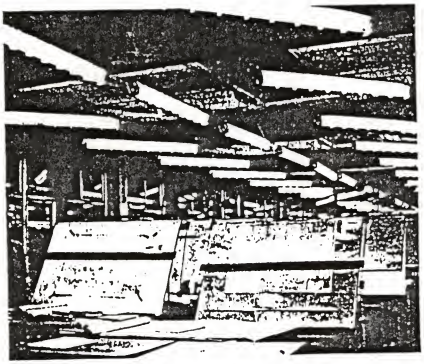


Figure 2: A drawing office illuminated by general lighting. (Source: Hopkinson & Longmore, 1959)

good lighting demands not only the provision of sufficient light to enable work to be done efficiently and in comfort, but also that the distribution of light in the visual field should make the work the natural focus of attention.

Distraction

The literature on the topic of distraction reveals all manner of complexities involved in determining it's effects.

Though many experiment have been carried out, the effect of external distraction on task performance still remains to be clarified. Tinker (1925), has shown that auditory distraction does decrease the accuracy of performance during intelligence testing. Hirose, and Matsumoto (1934), found decreased performance speed in the presence of distraction. Smith (1949), found that distraction increased the percentage of errors, while Harmon (1933), found no difference in percentage of errors for a similar task. Eschenbrenner (1971), found that both continuous and periodic distraction degraded performance on a complex tracking task. A similar result has been achieved by Percival (1980).

Although the findings are contradictory, there is some general agreement, however, that the nature of the task and also the nature and intensity of the external distraction are important factors in determining the

effects of distraction on performance. Broadbent (1971), has put forward a general model of selective filtering as applied to the selection and analysis of sensory information from competing sources. This theory suggests that an individual has a limited capacity channel for processing information, and interference would be likely to occur if two messages are to be handled simultaneously. But the interference would be less if the amount of information in the two simultaneous tasks is reduced, and the subject is able to shift his attention from one source to another.

Chowdhury (1974), conducted an experiment to study the effect of distraction on a letter cancellation task. He used 30 boys under three environmental conditions : No distraction, visual distraction , and an auditory distraction. Visual distraction was introduced through a stroboscope and an auditory distraction was given through an electric bell with a sound pressure level of 90 db. The duration of the task was four minutes for each subject and the distraction conditions were employed throughout the experiment. The results showed that the performance of the subjects under both the distraction conditions was significantly better than that of no distraction condition, but so far as distraction conditions are concerned, there was no significant difference in performance between the two conditions. It was suggested that if a task is very

easy, the subjects would do the work better under the distraction condition.

Another study has been conducted by Kahneman (1970), to study the effect of distraction on adults. His results showed that distraction can have a facilitative effect for easy tasks and a detrimental effect for a different task.

Knowledge of the effect of distraction on performance is still limited and inconclusive. Examination of previous researches indicates the need for more research to be conducted on the relationship between lighting sources, of distraction and performance.

The present study was designed to determine if the subjects, performing under task lighting or general lighting, were distracted by external source of distraction in the working environment. It was expected that the results of the present study would provide useful information to the lighting designer, particularly in relating the type of lighting and the degree of distraction to the subject's concentration/attention.

PROBLEM

The purpose of this study was to find out if an external distraction affects worker performance under task lighting as much as with general lighting. Past researches on illumination and visual performance involved testing the influence of type of lighting on worker's performance. This research introduced another factor external source of distraction induced by television, and determined how this affected performance.

Performance will be objectively measured by the accuracy to perform the task.

Specific hypothesis of this research are :

1. Performance under task lighting with distraction is better than under general lighting with distraction.
2. Regardless of the lighting conditions, performance with no distraction is better than with distraction.
3. Regardless of the distraction conditions, the experiment attempt to test the influence of the type of lighting on performance.

METHOD

This experiment involved four conditions. They were a combination of light (task lighting and general lighting) and distraction (presence/absence of distraction). Figure 3 lists the four conditions used in this study.

Thirty two subjects participated. They were divided into four groups each of size eight. Each of the groups was observed under all levels of task, but each group was assigned to only one combination of lighting and distraction factors on a random basis using the random number tables. The experimenter ran the subjects one at a time, and each subject was run under only one condition.

The task which was given to the subjects was a letter crossing task. They were given a series of letters and asked to cross certain sequences of letters.

The experiment was done in a room which was 180"x 144"x120" size. The arrangement of the furniture in the room was particularly set up for the purpose of running the experiment. The room had two doors, with a table and two chairs placed on both sides of the table, one for the subject and the other one for the experimenter on which he sat and watched the subject, and a small table on which a television and video recorder were placed at a distance of eight feet from the position of the subject on the right hand side of the subject. There

Condition	Light source	Presence/absence of distraction
1.	Task lighting	No distraction
2.	Task lighting	With distraction
3.	General lighting	No distraction
4.	General lighting	With distraction

Figure 3. The four experimental conditions

was a stopwatch, light meter , and 12 video tapes VHS format. Figures 4, 5, 6, and 7 shows the experimental room (the arrangement of the furniture and the four conditions of lighting and distraction). Figure 8 shows the arrangement of the table and the chairs. Finally, Figure 9 shows the arrangemet of the television and the video recorder. Table 2 lists the contents of the tapes.

Three tapes were assigned randomly to each subject. Table 3 shows the order of the tapes assigned to the subjects.

A Black & White television of size 11" plus a video recorder were provided as a source of distraction. The general lighting was provided by means of overhead Flourescent lighting, while task lighting was provided by an adjustable desk light having a 60 watt incandescent lamp. The illuminance was kept constant for both types of lighting at 100 lumens per square feet.

Subjects

Thirty two subjects participated. There were 26 males and six females with ages ranging from 19 to 32.

The experimenter recruited the subjects in two different ways. One was by asking people who were passing by the experimental room whether they were interested of being a subject in this study for 40 minutes. Another way of

Figure 4. Task lighting with no distraction.

Figure 5. Task lighting with distraction.

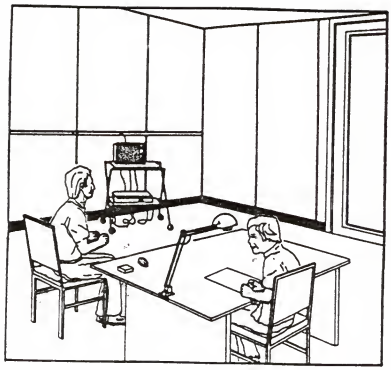


Figure 6. General lighting with no distraction.

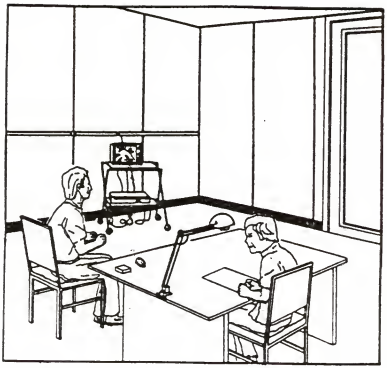


Figure 7. General lighting with distraction.

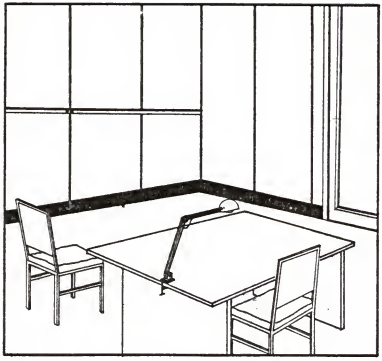


Figure 8. The arrangement of the furniture.

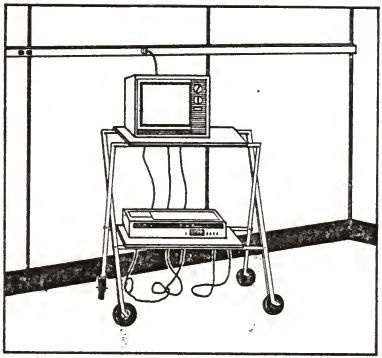


Figure 9. The arrangement of the television and the video recorder.

TABLE 2

The contents of the video tapes

Tape no.	Tape length (in minutes)	Contents of the tape	Program (in minutes)
1	120	ABBA Movie, and Olivia Newton John Movie	90 30
2	120	The Jazz singer Movie	120
3	120	Paul/Simon in Concert	120
4	120	Solid Gold " The best 40 songs in 1982 "	120
5	60	Benny Hill Show	60
6	60	Solid Gold (Rock songs, and dancer)	60
7	120	Air Supply in Concert	60
8	120	Blood Beach Movie Rock Songs	90 30
9	120	James Bond Movie	120
10	120	Rock songs	120
11	120	Benny Hill Show Solid Gold	60 60
12	120	Crystal Gail in Concert Rock and country songs	60 60

TABLE 3

The order of the tape assigned to the subjects

Subject no.	Tape order		
1	10	2	4
2	7	1	9
3	3	7	11
4	10	2	11
5	2	7	5
6	7	1	12
7	9	3	1
8	7	9	11
9	1	6	4
10	4	1	10
11	8	4	5
12	8	9	5
13	2	1	6
14	12	4	2
15	1	6	9
16	12	5	3

recruiting subjects was by passing a sign-up sheet of paper asking whether they were interested in earning class credit by being a subject in this study. People who were interested in participating in the experiment signed the paper and left their telephone numbers. The experimenter then called them up and made appointments.

Task

The task chosen was a mental task involving decision making along with accuracy. The subjects were given a series of letters. They were asked to cross certain sequences of letters. The tasks were written in the following way :

Task 1

You are to cross out consonants placed on either sides of X e.g.

C J R X D M F X K O X F L

W K A J X A L S X I N X N

Task 2

You are to cross out consonants placed on either sides of X, provided that the consonants are either preceded or followed by a vowel e.g.

C X R E T C O K X W M P H

M K X C I S X D F J L G E

Task 3

You are to cross out consonants placed on either sides of X, provided that the consonants are either preceded or followed by a vowel, but the vowel is not O or E e.g.

D C I F X M E N R S X J U

E L X P I R Q V O N X C I

Task 4

You are to cross out consonants placed on either sides of X, provided that the consonants are either preceded or followed by two vowels having K between them e.g.

C O K I D X J I K E L U N

F K U R X N O I C Q L H B

Task 5

You are to cross consonants placed on either sides of X, provided that the consonants are either preceded or followed by the vowels A and I (both) in any order but the vowels are not preceded or followed by the following letters K, R, and S e.g.

M A I D X M I A J P W K V

K I A F X N I A S H Q S D

Experimental Design

The appropriate lighting was switched on and the television switched on under the distraction condition before the subject entered the experimental room. The illumination level on the desk was checked to provide the exact illumination (100 footcandles). The illumination level of the desk lamp were adjusted by changing the height of the lamp and using a transformer.

When the subject entered the experimental room, he was asked to sit and was given an instruction sheet which read as in Figure 10. After the subject had read the instruction sheet, he was questioned by the experimenter to find out if he had properly understood the procedure. After the subject consented to participate in the study, he signed the " informed consent statement " form (see Figure 11).

INSTRUCTIONS

You are provided with five different sheets of papers. On each paper you are asked to cross out letters in a particular sequence, as indicated in the task description. You will also be given an evaluation sheet on which you have to rate the difficulty of each task. You will be given 7.0 minutes to complete each task.

There will be no discomfort nor risk in this experiment. However, you are free to stop your participation at any time. Naturally, I would prefer that you continue until the end so that I can get all of the needed data.

I will sit in the room doing some work , you need not to be bothered of my presence.

If you have any questions now or later, feel free to ask.

Thank you very much for being a subject for this experiment.

Figure 10. Instructions for the subjects.

Informed Consent Statement

Having read the instructions, I hereby freely agree to be a subject in this experiment.

S.S. #	Signature	Age	Sex (M/F)

Figure 11. " Informed Consent Statement " Form

The subject was given the tasks according to a randomization order (see Table 4). After the subject finished the first task, he was given an evaluation sheet on which he had to rate the difficulty of the task. After he finished with the evaluation sheet, he proceeded to do the second task. After the third task, the subject was given a 3.0 minutes break, during the break period, the experimenter prepared the materials for the remaining tasks.

Subjective Evaluation

After completion of all tasks, subjects were asked to rate the lighting condition on the basis of how easy or difficult the task was to see and perform under that level of illumination. The ratings were based on the Borg Relative Perceived Effort scale (Borg, 1962, cited by Gamberate, 1972).

6	7	8	9	10	11	12	13	14	15	16	17
	very very easy		very easy		easy		some what hard		hard		very hard

18	19	20
	very very hard	

In physical tasks the ratings correspond closely to heart rates (times ten). In non-physical tasks such as these, the ratings are simply indicators of difficulty (Santamaria, 1979).

TABLE 4

The order of the task assigned to each subject

Subject no.	Task order				
1	4	2	1	3	5
2	5	2	1	3	4
3	2	1	5	3	4
4	2	3	4	1	5
5	5	2	3	4	1
6	5	2	4	3	1
7	2	4	1	3	5
8	2	5	1	4	3
9	1	5	4	2	3
10	5	1	2	4	3
11	5	4	3	2	1
12	3	2	5	4	1
13	3	5	4	2	1
14	2	1	4	5	3
15	5	4	1	2	3
16	1	5	2	4	3
17	4	3	1	2	5
18	2	4	3	5	1
19	4	2	5	3	1
20	4	2	3	5	1
21	3	1	5	4	2
22	1	4	5	3	2
23	1	3	4	5	2
24	2	3	1	4	5
25	3	5	1	2	4
26	5	1	4	3	2
27	5	3	4	2	1
28	2	3	4	5	1
29	2	5	3	1	2
30	1	4	3	2	5
31	1	3	5	2	4
32	1	2	4	5	3

RESULTS

Subject Performance

Each subject performed the letter crossing task under one combination of light and distraction. Errors were the criterion of performance of the letter crossing task.

" Errors " were the number of letters mistakenly identified and crossed by the subject, and the number of letters which were not identified nor crossed by the subject. The errors are presented in Table 5.

Despite the fact that each subject was given a definite amount of time (7.0 minutes for each task) in which he/she was to perform the tasks, it was decided that the time taken to complete each task would be noted. In other words, if the subject completed the task within seven minutes, the time taken was recorded. An observation of Table 6 revealed that there were times when the subject finished the task earlier than seven minutes. But, since the subjects were allotted this definite time in which to complete each task, an analysis of these times was found to be unnecessary.

The data obtained from this study were analyzed using the Statistical Analysis System (Barr, Goodnight, Sall, Blair and Chiko, 1979) program.

Since the experiment involved two levels of lighting, two levels of distraction, and five tasks, a 2x2x5 factorial design was used to analyze the data at the alpha=0.05 significance level.

TABLE 5 Letter crossing task : Errors (no. of mistakes committed).

Light source	Presence/absence of distraction	Sub. #	Task 1	2	3	4	5	Sub. mean	Dist. mean	Light mean
		1	1	1	4	3	8	3.4		
		2	12	22	7	3	21	13.0		
		3	9	24	8	6	10	11.4		
	Distraction	4	0	1	2	2	14	3.8	7.2	
		5	2	20	22	6	25	15.0		
		6	1	0	5	3	18	5.4		
		7	1	0	3	3	7	2.8		
		8	0	0	3	2	7	2.4		
Task lighting	Mean		3.3	8.5	6.8	3.5	13.8			6.2
		9	3	4	2	5	19	6.6		
		10	3	6	7	3	21	8.0		
		11	0	3	6	9	13	6.2		
	No distraction	12	0	0	6	2	18	5.2	5.2	
		13	0	0	3	1	15	3.8		
		14	0	0	2	3	4	1.8		
		15	0	2	4	4	15	5.0		
		16	0	2	3	5	13	4.6		
	Mean		.75	2.1	4.1	4	14.8			
		17	11	29	8	6	15	13.8		
		18	22	25	28	26	38	27.8		
		19	4	6	4	17	40	14.2		
	Distraction	20	0	1	6	4	33	8.8	18.3	
		21	57	56	19	24	18	34.8		
		22	3	4	37	25	22	18.2		
		23	7	31	22	6	25	18.2		
		24	1	18	13	4	17	10.6		
General lighting	Mean		13.1	21.3	17.1	14	26			13.7
		25	10	33	12	4	19	15.6		
		26	3	0	5	4	12	4.8		
		27	1	0	12	2	20	7.0		
	No distraction	28	3	2	3	4	18	6.0	9.1	
		29	3	8	29	5	20	13.0		
		30	15	2	7	4	18	9.2		
		31	2	1	5	2	37	9.4		
		32	8	2	3	4	20	7.4		
	Mean		5.6	6	9.5	3.6	20.5			
	Over all mean		5.7	9.5	9.4	6.3	18.8			

The grand mean = 9.95

Distraction mean=12.75

No distraction mean= 7.15

TABLE 6

Letter crossing task : Time to perform the task. (in minutes)

Light source	Presence/absence of distraction	Sub. #	Task 1	2	3	4	5	Sub. mean	Dist. mean	Light mean
		1	5.3	6.0	6.0	5.0	4.5	5.4		
		2	3.5	4.5	4.0	4.0	7.0	4.6		
		3	3.0	6.3	5.0	6.0	5.0	5.1		
	Distraction	4	4.0	7.0	6.4	5.0	7.0	5.9	5.1	
		5	4.0	6.0	7.0	7.0	7.0	6.2		
		6	4.0	5.2	4.4	5.4	5.5	4.9		
		7	4.6	5.0	4.5	4.0	5.0	4.6		
		8	4.3	6.0	4.0	4.0	4.0	4.5		
Task lighting	Mean		4.1	5.8	5.2	5.1	5.6			5.1
		9	4.0	6.3	6.0	7.0	6.3	5.9		
		10	5.0	5.3	5.0	6.3	7.0	5.7		
		11	4.1	5.0	7.0	5.0	7.0	5.6		
	No	12	3.0	4.1	5.3	4.3	5.5	4.4	5.0	
	Distraction	13	4.2	6.1	4.2	5.2	6.0	5.1		
		14	4.3	5.1	4.3	4.5	4.2	4.5		
		15	3.6	4.4	3.1	3.1	4.2	3.7		
		16	5.0	5.0	6.0	4.0	5.5	5.1		
	Mean		4.1	5.2	5.1	4.9	5.7			
		17	5.3	7.0	4.3	7.0	7.0	6.1		
		18	4.0	5.3	6.0	6.3	7.0	5.7		
		19	4.0	6.1	7.0	7.0	6.0	6.0		
	Distraction	20	5.0	6.0	5.1	6.4	6.0	5.7	6.0	
		21	4.0	4.5	5.1	5.0	5.1	4.7		
		22	5.3	7.0	7.0	7.0	7.0	6.7		
		23	4.0	7.0	7.0	6.3	7.0	6.3		
		24	6.0	7.0	6.0	6.0	7.0	6.4		
General lighting	Mean		4.7	6.2	5.9	6.4	6.5			5.8
		25	4.3	7.0	6.4	6.5	7.0	6.2		
		26	5.0	7.0	6.1	7.0	6.0	6.2		
		27	4.0	6.2	7.0	7.0	7.0	6.2		
	No	28	5.0	5.2	4.0	4.1	6.0	4.9	5.6	
	Distraction	29	5.0	5.4	7.0	6.3	6.3	6.0		
		30	4.0	4.0	4.0	5.3	5.0	4.5		
		31	6.4	6.0	7.0	6.1	6.0	6.3		
		32	5.0	4.0	5.0	5.0	5.0	4.8		
	Mean		4.2	5.1	5.1	4.8	5.4			
	Over all mean		4.4	5.7	5.5	5.6	6.0			

The grand mean = 4.45
Distraction mean = 5.55
No distraction mean = 5.30

The model on which the analysis was done is shown in Figure 12. The summary analysis of variance is shown in Figure 13. The results of the analysis of variance done on the errors committed by the subjects is presented in Table 7.

The analysis of variance (Table 7) showed that lighting effect, distraction effect, and task effect were significantly different at the alpha=0.05 level. However, none of the interactions was statistically significant. Further analysis was carried out using Duncan's multiple range test (Table 8) for testing the differences among the tasks. It was found that the tasks were significantly different from one another.

Subject Ratings

After completion of each task, subjects were asked how difficult the task was. The results are presented in Table 9.

The ratings were made on Borg RPE Scale. The analysis of variance on the Borg Scale is shown in Table 10. The analysis of variance showed that there were significant differences among the tasks. Further analysis was carried out using Duncan's multiple range test for the task means Table 11. It was found that all the tasks were significantly different from one another, but not in the exact same order as their difficulty.

The interaction between distraction effect and the task was also found to be statistically significant at alpha=0.05

Model :

$$Y_{ijkm} = \mu + L_i + D_j + LD_{ij} + S_m(ij) + T_k + LT_{ik} + DT_{jk} + LDT_{ijk} + TS_{km}(ij) + \epsilon_o(ijkm)$$

$i = 1, 2 \quad j = 1, 2 \quad k = 1, 2, 3, 4, 5 \quad m = 1, 2, \ldots\ldots, 8$

Where :

Y_{ijkm} = the $(ijkm)^{th}$ observation

μ = over all mean

L_i = effect of the i^{th} light

D_j = effect of the j^{th} distraction

LD_{ij} = effect of the interaction of the i^{th} light with j^{th} distraction

$S_m(ij)$ = effect of the m^{th} subject within i^{th} light and j^{th} distraction

T_k = effect of the k^{th} task

LT_{ik} = effect of the interaction of the i^{th} light with k^{th} task

DT_{jk} = effect of the interaction of the j^{th} distraction with k^{th} task

LDT_{ijk} = effect of the interaction of the i^{th} light with j^{th} distraction with k^{th} task

$TS_{km}(ij)$ = effect of the interaction of the k^{th} task with m^{th} subject within i^{th} light and j^{th} distraction

$\epsilon_o(ijkm)$ = within error

Figure 12. The design of the experiment model

Analysis of variance table

Source		df	EMS	F
Between Subjects		npq-1		
(1)	L	p-1	$\sigma^2_\varepsilon + r\sigma^2_S + nqr\sigma^2_L$	(1)/(4)
(2)	D	q-1	$\sigma^2_\varepsilon + r\sigma^2_S + npr\sigma^2_D$	(2)/(4)
(3)	LD	(p-1)(q-1)	$\sigma^2_\varepsilon + r\sigma^2_S + nr\sigma^2_{LD}$	(3)/(4)
(4) Sub. within groups(error)		pq(n-1)	$\sigma^2_C + r\sigma^2_S$	
Within Subjects		pq(n-1)		
(5)	T	r-1	$\sigma^2_C + \sigma^2_{TS} + npq\sigma^2_T$	(5)/(9)
(6)	LT	(p-1)(r-1)	$\sigma^2_\varepsilon + \sigma^2_{TS} + nq\sigma^2_{TL}$	(6)/(9)
(7)	DT	(q-1)(r-1)	$\sigma^2_\varepsilon + \sigma^2_{TS} + np\sigma^2_{DT}$	(7)/(9)
(8)	LDT	(p-1)(q-1)(r-1)	$\sigma^2_\varepsilon + \sigma^2_{TS} + n\sigma^2_{LDT}$	(8)/(9)
(9) T*Sub. within groups		pq(n-1)(r-1)	$\sigma^2_\varepsilon + \sigma^2_{TS}$	

Assumes L, D, and T are fixed factors

Figure 13. Summary of the analysis of variance table

TABLE 7

Letter crossing task : Analysis of variance on errors committed

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR>F
L	1	2265.03	2265.03	14.91**	.0006
D	1	1265.63	1265.63	8.33**	.0074
L*D	1	525.63	525.63	3.46	.0734
S(L*D)	28	4252.3	151.88		
T	4	3507.96	876.99	14.31**	.0001
L*T	4	72.04	18.01	0.29	.8813
D*T	4	315.31	78.83	1.28	.2794
L*D*T	4	52.94	13.26	0.21	.9290

Alpha = 0.05 significance level

** Highly significant

* Significant

TABLE 8

Letter crossing task : Duncan's multiple range test for the task means as errors(no. of mistakes committed) is the criterion

Task No.	Means	N	Grouping
5	18.75	32	A
2	9.47	32	B
3	9.38	32	C
4	6.28	32	D
1	5.69	32	E

Alpha = 0.05 significance level

Means with the same letter are not significantly different.

TABLE 9

Letter crossing task : Subject ratings for the difficulty of each task

Light source	Presence/absence of distraction	Sub. #	Task 1	2	3	4	5	Sub. mean	Disst. mean	Light mean
		1	10	12	11	14	17	12.8		
		2	8	10	12	13	14	11.4		
		3	10	12	12	12	13	11.8		
	Distraction	4	9	14	13	13	15	12.8	12.5	
		5	9	10	15	13	16	12.6		
		6	9	12	14	16	15	13.2		
		7	8	10	12	13	15	11.6		
		8	11	13	14	14	16	13.6		
Task lighting	Mean		9.3	11.6	12.9	13.5	15.1			12.0
		9	10	11	12	13	14	12.0		
		10	11	9	13	14	16	12.6		
		11	8	9	11	10	12	10.0		
	No	12	8	11	12	15	14	12.0	11.7	
	Distraction	13	10	13	13	14	15	13.0		
		14	9	10	11	13	12	11.0		
		15	10	11	10	11	12	10.8		
		16	7	11	13	14	14	11.8		
	Mean		9.1	10.6	11.9	13	13.6			
		17	9	12	14	14	17	13.2		
		18	11	13	15	14	17	14.0		
		19	11	11	11	17	17	13.4		
	Distraction	20	6	11	10	12	15	10.8	12.5	
		21	8	10	12	14	15	11.8		
		22	11	13	13	15	15	13.4		
		23	8	10	11	13	14	11.2		
		24	11	11	13	13	13	12.2		
General lighting	Mean		9.4	11.4	12.4	14	15.4			12.3
		25	9	13	13	13	15	12.6		
		26	11	13	13	14	12	12.6		
		27	9	11	13	12	14	11.8		
	No	28	12	12	12	13	15	12.8	12.0	
	Distraction	29	11	11	13	12	14	12.2		
		30	10	11	13	14	14	12.4		
		31	9	8	11	11	11	10.0		
		32	11	12	12	12	14	12.2		
	Mean		9.6	11.1	12.4	12.6	13.5			
	Over all task mean		9.5	11.3	12.4	13.3	14.4			

The grand mean = 12.1
Distraction mean = 12.5
No distraction mean = 11.9

TABLE 10

Letter crossing task : Analysis of variance on subject ratings

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR>F
L	1	2.025	2.025	0.43	.517
D	1	15.625	15.625	3.32	.0792
L×D	1	1.6	1.6	0.34	.5646
S(L×D)	28	131.85	4.7		
T	4	461.037	115.259	95.4**	.0001
L×T	4	1.787	.445	.37	.8298
D×T	4	17.187	4.295	3.55**	.0091
L×D×T	4	6.587	1.646	1.36	.2516
T×S(L×D)	112	135.4	1.208		

Alpha = 0.05 significance level

** Highly significant

* Significant

TABLE 11

Subject's ratings : Duncan's multiple range test for the task means

Task No.	Means	N	Grouping
5	14.40	32	A
4	13.28	32	B
3	12.40	32	C
2	11.25	32	D
1	9.50	32	E

Alpha = 0.05 Significance level

Means with the same letter are not significantly different

level Table 10. Further analysis was carried out for the interaction means using Duncan's multiple range test Table 12.

It was found that all means were different from each other except the following means :

(Distraction with task 4), and (no distraction with task 5).

Similarly, non significant differences were found among (no distraction with task 3), (no distraction with task 4), and (distraction with task 3).

Finally, none of the other interactions in Table 10 was ststistically significant.

Number of Look-ups

Another response variable was the number of times the subject looked at (was distracted by) the television.

As mentioned previously, the experimenter ran the subjects one at a time, exposed them to only one combination of light and distraction sources. While the subject performed, the experimenter recorded the number of times the subject looked-up at the television. The subject was unaware of the fact that this was being observed. The data are presented in Table 13. The results of the analysis of variance conducted on the number of look-ups are presented in Table 14. From the analysis of variance, the distraction effect was found to be highly significant at alpha=0.05. Furthermore, the analysis of variance showed significant difference among the tasks. Therefore, it was decided to carry further analysis using

TABLE 12

Subject's ratings : Duncan's multiple range test for the interaction between task and distraction means

D	T	Means	N	Grouping
1	5	15.25	16	
1	4	13.75	16	A
2	5	13.62	16	A A
2	4	12.81	16	B
1	3	12.62	16	B B
2	3	12.18	16	B B
1	2	11.50	16	
2	2	11.0	16	
2	1	9.68	16	
1	1	9.31	16	

Alpha = 0.05 Significance level

Means with the same letter are not significantly different

TABLE 13

Letter crossing task : The number of Look-ups (No. of times the subject looked at the television) data

Light source	Presence/absence of distraction	Sub. #	Task 1	2	3	4	5	Sub. total	Dist. total	Light total
		1	2	2	1	2	2	9		
		2	1	0	1	0	1	3		
		3	1	0	2	1	0	4		
	Distraction	4	1	0	0	0	1	2	30	
		5	2	1	0	1	1	5		
		6	1	0	0	1	1	3		
		7	1	1	0	0	0	2		
		8	0	1	0	0	1	2		
Task lighting	Total		9	5	4	5	7			30
		9	0	0	0	0	0	0		
		10	0	0	0	0	0	0		
		11	0	0	0	0	0	0		
	No	12	0	0	0	0	0	0	0	
	Distraction	13	0	0	0	0	0	0		
		14	0	0	0	0	0	0		
		15	0	0	0	0	0	0		
		16	0	0	0	0	0	0		
	Total		0	0	0	0	0			
		17	2	2	1	2	3	10		
		18	2	2	3	1	3	11		
		19	1	0	1	0	0	2		
	Distraction	20	1	0	0	1	0	2	55	
		21	1	0	0	1	0	2		
		22	1	0	0	1	1	3		
		23	1	0	1	0	0	2		
		24	6	5	5	4	3	23		
General lighting	Total		15	9	11	10	10			55
		25	0	0	0	0	0	0		
		26	0	0	0	0	0	0		
		27	0	0	0	0	0	0		
	No	28	0	0	0	0	0	0	0	
	Distraction	29	0	0	0	0	0	0		
		30	0	0	0	0	0	0		
		31	0	0	0	0	0	0		
		32	0	0	0	0	0	0		
	Total		0	0	0	0	0			
	Over all task total		24	14	15	15	17			

The grand total = 85
Distraction total = 85
No distraction total = 0

TABLE 14

Letter crossing task : Analysis of variance for the number of Look-ups (no. of times the subject looked-up at the television)

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR>F
L	1	3.6	3.6	1.169	.2888
D	1	44.1	44.1	14.327**	.0008
L*D	1	3.6	3.6	1.169	.2888
S(L*D)	28	86.2	3.07		
T	4	2.08	.52	2.73*	.0319
L*T	4	.462	.115	.60	.65
D*T	4	2.087	.52	2.73*	.0319
L*D*T	4	.46	.115	.6	.65
S*T(L*D)	112	21.30	.19		

Alpha = 0.05 Significance level

** Highly significant

* Significant

Duncan's multiple range test (Table 15) to test the task means. It was found that all tasks were significantly different from one another except task 3 and task 4.

From the analysis of variance (Table 14), the interaction between distraction effect and the task was found statistically significant. Further analysis was carried out for testing the interaction means (Table 16) using Duncan's multiple range test. It was found that the following means were non significantly different : (Distraction with task 2), (distraction with task 3), and (distraction with task 4). Similarly, (no distraction with task 1), (no distraction with task 2), ..., (no distraction with task 5).

The rest of the interaction means were found statistically different.

Finally, and from Table 14, none of the following effects was statistically significant (L, L×D, and L×D×T).

TABLE 15

Number of Look-ups : Duncan's multiple range test for the task means

Task No.	Means	N	Grouping
1	.75	32	A
5	.50	32	B
3	.46	32	C
4	.46	32	C
2	.44	32	C D

Alpha = 0.05 Significance level

Means with the same letter are not significantly different

TABLE 16

Number of look-ups : Duncan's multiple range test for the interaction between task and distraction means

D	T	Means	N	Grouping
1	1	1.5	16	A
1	5	1.0	16	A
1	4	0.93	16	A B
1	3	0.93	16	A B
1	2	0.87	16	A B
2	1	0.0	16	C
2	2	0.0	16	C
2	3	0.0	16	C
2	4	0.0	16	C
2	5	0.0	16	C

Alpha = 0.05 Significance level

Means with the same letter are not significantly different

DISCUSSION

Subject Performance

The performance of the letter crossing task was measured by the number of errors subjects committed in the task. The analysis of variance (Table 7) showed highly significant differences in the subject performance under the two lighting conditions. The type of lighting seems to have high influence on the performance.

This finding shows disagreement with results of the Lion study (1964), in which she found that the type of lighting didn't have any effect on the performance for the clerical task.

One explanation for the conflicting results is the task difference. The previous study involved three manipulative and one inspection task. They consisted of grading ball bearings on size, needle threading, measuring steel rods, and reading columns of paired numbers. The task for the present study was a letter crossing task.

Another explanation is the difference of experimental design. In the Lion study, a " Same subject design " was used. Each subject ran once under tungsten and once under fluorescent lighting. In the present study, an " Independent groups design " was used. Each subject was run under only one combination of lighting and distraction.

The mean number of errors committed in the tasks under each lighting condition (Table 5) was plotted as shown in Figure 14. From the plot, it can be seen that there was increasing trend in the number of errors committed as one moves from task 1 to task 5 under the task lighting condition.

However, the errors did not follow the same trend under the general lighting condition. The curve showed an increase in the number of errors in task 2, then, the curve declined sharply. Finally, the curve showed another increase in the number of errors in task 5.

Inspection of the subject performance under the two lighting conditions (Table 5) shows that the mean number of errors committed under general lighting condition was about (13.7) which was twice the number of errors committed under the task lighting condition.

One explanation for the difference in the lighting means could be due to the effect of background distraction from outside the experimental room on subject performance.

Another explanation could be due to the fact that subjects who performed under the task lighting system were able to control or adjust the direction of the light on the work surface, while those who performed under the general lighting condition did not have any control on the direction of the light.

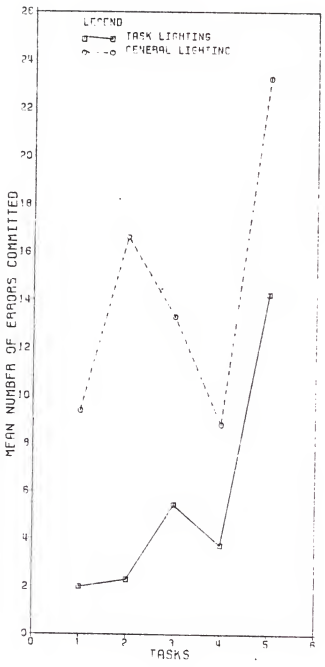


Figure 14. The mean number of errors committed under the two lighting conditions (Task lighting, and General lighting)

A lower number of errors committed under task lighting than under general lighting suggests that performance is better under task lighting than under general lighting.

As a conclusion, the hypothesis of better performance under task lighting has been corroborated by the results obtained in this study.

The external source of distraction has been found to affect the performance. The analysis of variance (Table 7) showed highly significant difference in the subjects performance under the two distraction conditions (Presence/absence of distraction).

This finding shows agreement with results of the Hirose and Matsumoto study (1934), in which they found decreased performance speed in the presence of distraction. The finding is also in agreement with the results of the Smith study (1949), in which he found that distraction increased the percentage of errors. However, the finding shows disagreement with the Chowdhury study (1974), in which he suggested that if a task is very easy, the subjects would do the work better under the distraction condition than under the normal condition (no distraction).

One explanation for the conflicting results could be due to the difference in the experimental procedure. In the previous study, two types of distraction, visual and auditory, were introduced when the subjects were performing the letter

cancelation or letter crossing task. The visual distraction was applied through a stroboscope, while the auditory distraction was introduced through an electric bell with a sound pressure level of 90 db. The external distraction in the present study was induced by television which is more a source of entertainment than of disturbance.

Another explanation is the difference of experimental design. In Chowdhury's study, the subjects were divided into three equal groups of 10 subjects each, and each one of the groups run under all conditions, or in other words, a " Same subject design " was used. However, in the present atudy, an " Independent groups design " was used. Each subject was run under only one combination of lighting and distraction condition.

Subject performance (errors committed) under the two distraction conditions was plotted as shown in Figure 15. From the figure, it seems that, the pattern of the two curves which represent the performance under the two distraction conditions was similar. It can be seen that, both curves showed deterioration in the performance as one moves from task 1 to task 2, and from task 4 to task 5. Only one difference between the two patterns was observed . The difference was in task 3. Those who performed under the influence of distraction showed improvement in the performance, while those who performed in the absence of distraction showed deterioration in task 3.

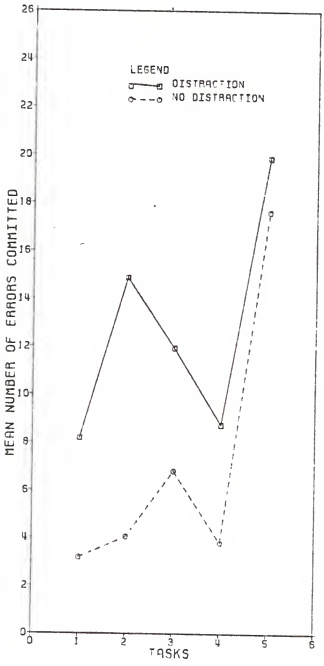


Figure 15. The mean number of errors committed under the two distraction conditions (Presence/ absence of distraction).

In general, it can be seen from Figure 15 that, the performance tended to be somewhat better for those who performed in the absence of distraction source (rather than those who performed under the influence of distraction).

As a conclusion, the hypothesis of better performance under the absence of distraction has been corroborated by the results obtained in this study.

Finally, the non significant interaction results which have been observed lead to the conclusion that the task did not have any relevance to the type of lighting or to the presence/absence of distraction sources. Thus, the hypothesis of better performance under task lighting with distraction than under general lighting with distraction was not confirmed.

Subject Ratings

The data for the Borg Scales (perceived difficulty) was presented in Table 9. The ratings were made on the Borg RPE Scale, where

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	very very easy		very easy		easy		some what hard		hard		very hard		very very hard	

Table10 gives the summary of the analysis of variance. From the table, highly significant differences among the tasks was observed. Inspection ofthe task means (Table 9) showed that task 1 was perceived to be the task that required the least effort. It received a mean rating of (9.5), which

would place it between " Very easy " and " Fairly easy " on the Borg Scale. However, task 5 was given a mean rating of (14.4), and this would be between " Fairly hard " and " Hard "

The interaction between the task and the distraction effect namely (DT) was found to be highly significant · (Table 7), indicating that, the ratings for a given task are affected according to the level of distraction , or in other words, the change from no distraction to distraction produced an increase in the ratings.

Similarly, the ratings at a given level of distraction are affected according to the task level, the change from one task to another more difficult produced an increase in the ratings, when the level of distraction is the same.

To investigate the relation between subject performance (no. of errors committed) and subject ratings for the difficulty of each task, it was decided to find the correlation between them. The over all task means for both measures were obtained and tabulated as shown in Table 17, and plotted against each other as shown in Figure 16. A high correlation* was found between subject performance and subject ratings ($r = 0.693$). From Figure 16, it seems that

---

* Significant at alpha = 0.05 significance level

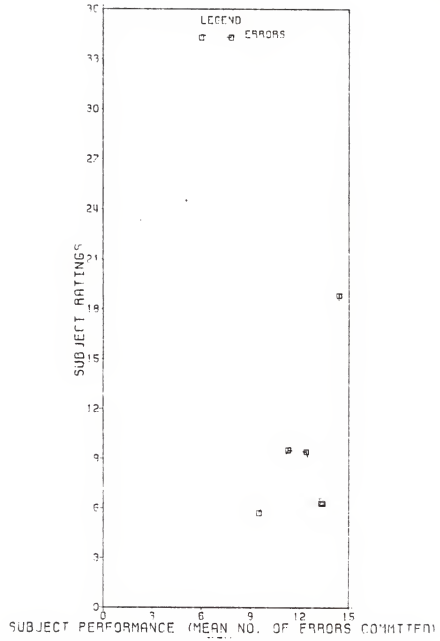
TABLE 17

Correlation between subject performance and the number of look-ups

Task no.	Subject performance	Total number of look-ups	Task mean
1	5.7	24	14.9
2	9.5	14	11.7
3	9.4	15	12.2
4	6.3	15	10.6
5	18.8	17	17.9
Mean	9.9	17	

The grand mean = 13.45

The correlation coefficient r = 0.693



r=0.693

Figure 16. Relation between subject ratings and subject performance

high ratings were given to the difficult tasks and vice vesa.

Number of Look-ups

The data obtained for the number of look-ups (no. of times the subject looked-up at the television) are presented in Table 13. The analysis of variance conducted on the number of look-ups is shown in Table 14.

A highly significant difference in the number of look-ups under the two distraction conditions was found. Thus, the presence/absence of distraction seems to have high influence on the number of look-ups.

This finding shows agreement with results of the Hopkinson and Longmore study (1959), in which they said : " The attention can be distracted by bright or a highly colored object in the field of view a little a way from the object of regard. " with a slight difference that is, the bright ar a highly colored object which has been mentioned in the previous restudy presented in this study by television. In other words, the television acted as a distraction source in the present study.

Significant differences among the tasks were found (Table 14). Inspection of the over all task totals (Table 13) showed that the greatest number of look-ups occured

with task 1, which might be considered as an easy task.

However, the least number of look-ups occured with task 2 which was slightly more difficult than task 1.

Finally, the interaction between task and distraction effect namely (DT), was found statistically significant (Table 14). This indicates that, for a given task, the number of look-ups are affected according to the level of distraction, or the change from no distraction to distraction produced an increase in the look-ups.

Similarly, the look-ups at a given level of distraction are affected according to the task level, or the change from one task to another more difficult produced an increase in the look-ups, while the level of distraction is the same. This could be due to a psychological reason, where the subject feels inconvenience when he/she changed from an easy task to a relatively more difficult task.

To investigate the relationship between subject performance (no. of errors committed) and the number of look-ups (no. of times the subject was distracted by the television), it was decided to find the correlation coefficient between the two measures. The over all task means for the subject performance and the total number of look-ups which occured in the five tasks were

tabulated as shown in Table 17, and plotted against each other as shown in Figure 17.

Surprisingly, the data yielded a correlation of ($r=-0.23$)[1], indicating a weak negative relationship between subject performance and the number of look-ups. From the figure, it is clear that as the number of look-ups increased a little (or no) improvement occured in the suject performance and vice versa. No explanation could be provided here to explain this strange finding.

To investigate the relationship between the number of look-ups and subject ratings for the difficulty of each task, the over all task means for subject ratings and the total number of look-ups which occured in the five tasks were tabulated as shown in Table 18, and plotted against each other as shown in Figure 18.

The correlation coefficient was found to be ($r=-.67$)[2], indicating negative correlation between the two measures. This negative relation caused by the effect of the outlier (task 1). By removing the first pair from the data, a strong positive correlation coefficient was resulted ($r=0.94$). From Figure 18, and ignoring the first pair of the data, itis clear that increases in the number of look-ups resulted higher ratings for the difficulty of each task.

---

1 Non significant at alpha = 0.05 significance level
2 Significant at alpha = 0.05 significance level

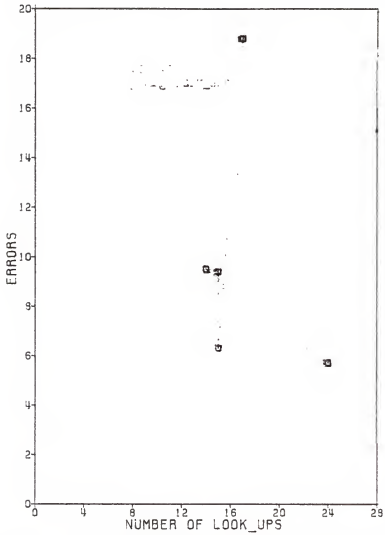


Figure 17. RELATION BETWEEN SUBJECT PERFORMANCE AND NO.OF LOOK_UPS (NO. OF TIMES THE SUBJECT LOOKED AT THE TELEVISION)

TABLE 18

Correlation between subject ratings and the number of look-ups

Task no.	Subject ratings	Total number of look-ups	Task mean
1	9.5	24	16.8
2	11.3	14	12.6
3	12.4	15	13.7
4	13.3	15	14.1
5	14.4	17	15.7
Mean	12.2	17	

The grand mean = 14.6

The correlation coefficient r= -.67

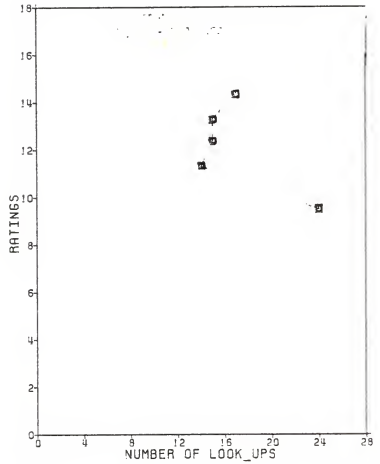


Figure 18. RELATION BETWEEN SUBJECT RATINGS AND NO. OF LOOK_UPS (NO. OF TIMES THE SUBJECT LOOKED AT THE TELEVISION)

Implications

It was hypothesized earlier that, performance under task lighting with distraction is better than under general lighting with distraction. One major finding of the present study was that, the study found no difference in the subject performance under the two type of lighting in the presence of distraction sources.

A possible explanation for that difference could be due to the nature of the task. The kind of the task the subjects were involved in, was so simple that any combination of lighting and distraction sources did not affect the performance. Thus, the study suggests for more research be conducted on the relationship between lighting sources, of distraction and performance using different kind of tasks.

It was expected that the results of this study would provide useful information to the lighting designer, particularly in relating the type of lighting and the degree of distraction to the subject's concentration/attention.

Another finding, distraction was found to have a high influence on the subject ratings and the number of look-ups.

Finally, and as an implication, the study suggests that, the analysis of the number of look-ups should be made independent of any experiment, and use equipments such as video cameras for observing the number of look-ups.

CONCLUSIONS

The main objective was to find out if external distraction affects worker performance under task lighting as much as with general lighting.

Some conclusions can be drawn upon this study :

1. The hypothesis of better performance under task lighting with distraction was not confirmed.
2. The hypothesis of better performance under no distraction condition was confirmed.
3. The type of lighting was found to have high influence on the performance

REFERENCES

Chowdhury, B. P. and Sen, A. Effect of distraction on a letter cancellation task. Psychological Studies, 1974, 19, 69-77.

Gawron, V. J. Performance effects of noise intensity, psychological set, and task type and complexity. Human Factors Society, 1982, 24(2), 225-243.

Guerra, D. R. Task ambient lighting-the issues persist, a survey of the Pros and Cons . Lighting Design & Applications, 1979, 9(1), 19.

Henderson, R. L., McNelis, J. F. and Williams, H. G. A survey and analysis of important visual tasks in offices. Journal of the Illumination Engineering Society, 1975, 4(2), 150-153.

Illuminating Engineering Society of North America. American National Standard Practice for Industrial Lighting, ANSI/IES RP-7-1979.

Lemons, T. M. and Cole, J. M. Scale models used to investigate office task lit systems furniture. Lighting Design & Application. 1977, 7(10), 4-8.

Lion, J. S. The performance of manipulative and inspection tasks under tungsten and fluorescent lighting. Ergonomics, 1964, 7, 51-61.

Longmore, J. and Hopkinson, R. G. Attention and distraction in the lighting of work-places. Ergonomics, 1959, 2, 321-333.

Misra, S. Lighting for a visual inspection task. Unpublished Master's Thesis, , Industrial Engineering Department, Kansas State University, 1982.

Taylor, L. H., Sucov, E. W. and Shaffer, D. H. Office lighting and performance. Lighting Design & Application, 1975, 5(5), 30-36.

Weston, H. C. Sight light and efficiency. London : H.K. Lewis, 1949.

Williams, H. G. Office lighting and energy. Lighting Design & Applications, 1975, 5(1), 6.

Yuan, S. A study of task light systems : HID KIOSKS and furniture mounted flourescent lighting system. Unpublished Master's Thesis, Kansas State University, 1980.

DOES EXTERNAL DISTRACTION AFFECT WORKER PERFORMANCE UNDER TASK LIGHTING AS MUCH AS WITH GENERAL LIGHTING

by

RAIED AL-MISHHEDANI

B.A. (Statistics), College of Economics and
Administration, Al-Mustansiriyah University
Baghdad, Iraq, 1976

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Industrial Engineering
KANSAS STATE UNIVERSITY
Manhattan, Kansas

1984

ABSTRACT

The main objective of this study was to find out if an external distraction affects worker performance under task lighting as much as with general lighting.

The study involved four conditions of lighting and distraction. They were : Task lighting with distraction, task lighting with no distraction, general lighting with distraction, and general lighting with no distraction.

Thirty two subjects participated. They were divided into four groups each of size eight. Each of the groups was observed under all levels of task, but each group was assigned to only one combination of lighting and distraction on a random basis. Subjects were run one at a time, and each subject was run under only one condition.

Three sets of data were collected. Subject performance (no. of errors committed in the letter crossing task), subject ratings, and the number of look-ups (no. of times the subject was distracted by the television).

As a results of this study, and for subject performance, the study found highly significant differences in the subject performance under the two lighting conditions, under the two distraction conditions, and among the tasks. However, for subject ratings, highly significant interaction between task and distraction effect, and among the tasks were observed.

Significant correlation between subject performance and

subject ratings was observed.

Finally, for the number of look-ups, the interaction between distraction effect and task, distraction effect, and task effect were all found statistically significant.

No correlation was found between subject performance and the number of look-ups. Significant correlation between subject ratins and the number of look-ups